Letters to the Editor

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6

PERIODICITY IN NUCLEAR BINDING ENERGY AND CORRELATION BETWEEN THE ISOTOPES OF DIFFERENT NUCLEI

A. K. DUTTA

PALIT PROFESSOR OF PHYSICS, UNIVERSITY COLLEGE OF SCIENCE, CALCUTTA-9.

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The binding energy of the nuclei is measured by the difference between the observed masses of the nuclei and the sum of the masses of the constituent nucleons. To explain the variation of the binding energy E for different nuclei, Bethe and Weiszcäker have proposed the following relation

$$E = -a_1A + a_2A^{2/3} + a_3\frac{Z^2}{A^{1/3}} + a_4\frac{(N-Z)^2}{4A}$$

where A is the atomic number, N and Z are the numbers of neutrons and protons and a_1, a_2, a_3 and a_4 are constants to be fixed by actual comparisons. The formula above, though broadly successful, is not adequate to explain precise mass data closely. Various efforts (Green, 1958 and Seeger, 1961) have been made to improve upon the Bethe-Weiszäcker relation by including pairing correction distinguishing nuclei composed of different combination of even and odd number of protons and neutrons, effects of shell structure and nuclear deformation and so on; however, the agreement of these improved formulae with observed data is not satisfactory. In view of this unsatisfactory situation, it is considered worthwhile to emphasize the deviations of the Bethe-Weiszacker relation from the latest mass data of as many stable nuclei as are available and to see whether the deviations indicate any regular and systematic pattern.

Here we have plotted for different nuclei ΔM, the deviation of the experimentally observed binding energy (in MeV) from the Bethe-Weiszacker relation

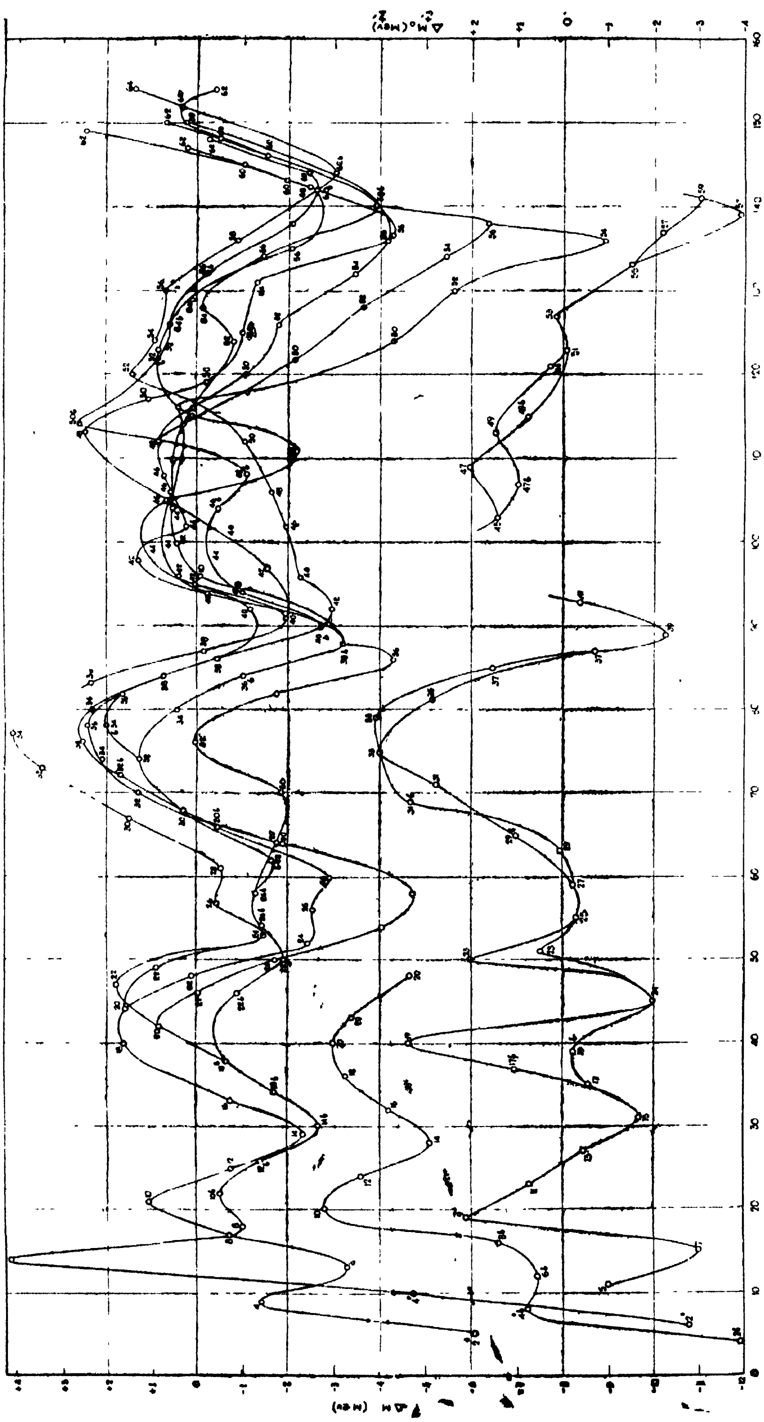

Fig. 1. ΔM–A curves for even and odd charge stable nuclei with scales on the left and right sides respectively. Few unstable nuclei are marked with asterisk. The charges are indicated at the points. Most strongly bound nuclei are denoted by 'b' in addition.

with the values of the four constants as given by Green (1954). The experimental data have been taken from the work of Duckworth (1958) up to atomic number $Z = 62$ for which range the nuclear masses of all the stable isotopes are given except for $Z = 44$. For the selection of the points through which to draw a certain curve, we have divided the nuclei into two sets, one with odd values of Z and the other with even values of Z. The set of even values of Z is further subdivided into categories depending upon the excess number of neutrons over protons, whether it is none, one, two, three and etc. When the minimum excess of neutrons changes from one stable element to the next one, the curve is drawn connecting the two minimum excess isotopes even though the excess of neutrons is not the same along the curve. Further when the total number of stable isotopes varies from one element to the next, there is branching or merging of curves depending upon whether the number of isotopes increases or decreases at that point; in the case of ambiguity mostly, near the region of branching or merging the points are so chosen that the curve connecting them follows a regular smooth course.

The curves drawn in accordance with the principles stated above show regular undulating character with a smooth run, the maxima and minima of all the different courses fall at near about the same region of mass number.

From the above curves it is possible by way of interpolation to predict the values of masses of the isotopes of $Z = 44$ which are not tabulated by Duckworth. The element $Z = 44$ has seven stable isotopes with mass number $A = 96$, 98, 99, 100, 101, 102 and 104; Duckworth has given the masses of the isotopes with $A = 96$, 102 and 104. By the method of interpolation of curves we have calculated the possible masses of the remaining isotopes. After the completion of this work it has come to our notice that Everling (1960) has supplied the masses of $A = 98$ and 99 as well as of $A = 96$, 102 and 104, and the agreement of our extrapolated results with Everling's for $A = 98$ and 99 is as good as that of Everling's results with Duckworth's for 96, 102 and 104.

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